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Mineral Resource

The Energy Scene—An Arizona Perspective

by Dr. Madan M. Singh, Director

Everyone enjoys the modern amenities of life – air conditioning or heat depending on the weather, refrigerators, televisions, microwaves, computers. Almost anything that we use depends on electricity. It is taken for granted that we will have enough electrical power available for our use. However, the power shortages in South Africa at the present time and the rolling blackouts that California experienced two years ago should give us pause. Last year 45 coal power plants in development were cancelled or put on hold, but long-term electricity requirement is growing at the rate of 1.2 percent per year.

The economic downturn this year aided by the high price of oil (recently $111 per barrel) is expected to slow the growth of power consumption; but this is expected to change next year. The amount of power produced from coal will remain essentially flat from last year, or decrease very slightly, but should increase next year. Power from other sources will decline this year and then grow somewhat next year, except pumped storage hydroelectric that continues to decrease.

The sources of electric power listed in Table 1 constitute over 96 percent of the total power generated. In addition, there are smaller amounts of electricity produced and used by the commercial and industrial sectors.

It is clear that nearly 50 percent of the power is generated from coal. There is considerable concern that burning coal generates carbon dioxide that contributes to global warming. It is unlikely that we will substitute all that energy from other sources during the next few decades. Besides, there are large deposits of coal in the country, and one of the major goals of the nation is to wean itself from foreign sources of oil. About 20 percent of the power is produced from natural gas that burns cleaner than coal; a drawback, however, is the amount imported.

Nuclear Power

Nuclear power provides nearly 20 percent of the nation's electricity. This is a clean source that does not produce any carbon dioxide emissions, and so does not contribute to climate change. Some environmental groups have suggested that nuclear power would contribute so much carbon that this would match that produced from coal or natural gas. This statement has been contradicted by most scientists. Dr. El-Baradei, Director General of the International Atomic Energy Agency, has stated (2005) "Nuclear power emits virtually no greenhouse gases. The complete nuclear power chain, from uranium mining to waste disposal, and including reactor and facility construction, emits only two to six grams of carbon per kilowatt-hour. This is about two orders of magnitude below coal, oil, and even natural gas."

There is a misplaced concern about radiation. The fear of nuclear power plants has increased after the accidents at Three Mile Island (TMI) and Chernobyl, in Ukraine. In the case of TMI there were several enquiries at various levels of government and a considerable amount of research performed to determine the cause of the accident and develop procedures to prevent its recurrence. A health group tracked 30,000 persons from the area for 20 years but did not find any evidence that there were any detrimental effects that could be attributed to radiation exposure from the TMI failure. It should be noted that there was not a single death caused by the TMI accident.

Merger Bill Voted Down

House Bill 2584, which would have merged the Department of Mines and Mineral Resources into the Arizona Geological survey, was voted down by the Environment Committee of the State House of Representatives on February 27.

The Department would like to convey our sincere thanks to everyone for their support in defeating this bill. We hope to continue to provide the service that has earned us that support.

At Chernobyl the situation was different. There were problems with the design, engineering, shielding, and safety practices, which were compounded by the weather. Unlike all U.S. nuclear plants there was no containment structure surrounding the reactor. The person running the plant was a political appointee, with little knowledge of nuclear plants, and the person sent from Moscow to take charge of the crisis did not permit immediate evacuation – so as to not cause a panic! Later, of course, large-scale evacuation (116,000 persons) did occur.

In 2000, an UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) report on the Chernobyl accident stated "There is no scientific evidence of increases in overall cancer incidence or mortality or non-malignant disorders that could be related to radiation exposure. The risk of leukemia, one of the main concerns owing to its short latency time, does not appear to be elevated, not even among recovery operation workers." The Chernobyl Forum reported in 2005, "The death toll stands at fifty directly attributable to radiation exposure sustained by reactor staff and emergency workers. . . There still have been no increases in leukemia or in birth defects. A slight increase in the cancer rate among liquidators does not differ statistically from the general population."

In spite of these accidents many countries in the world are producing large percentages of their electricity from nuclear plants. Many lessons have been learned from these events, however. Even Ukraine continues to depend on nuclear plants for its electric power. It has 15 reactors in operation, producing 47 percent of its power in 2007. It plans to add 11 new reactors and renovate 11 existing units by 2036. After a hiatus of nearly three decades, the United States is now planning on building new nuclear plants; the United States is still the leading producer of electric power from nuclear sources, having generated 787.2 billion kilowatt-hours (kwh) in 2006. France is the next largest producer of nuclear power, 428.7 billion kwh in 2006. Among the states, in 2006, Illinois generated 94.2 billion kwh which is 48.8 percent of it power from nuclear plants, while New Jersey produced 32.6 billion kwh, which constitutes 53.2 percent of its electricity; Arizona generated only 23.0 percent (24.0 billion kwh).

There are nearly 30 new nuclear plants under consideration for construction in the United States, of which three have been approved by the Nuclear Regulatory Commission (NRC). There are 104 reactors currently in operation. The Energy Policy Act of 2005 promises a tax credit of 1.8 cents per kwh for the first 6,000 megawatts of nuclear generation capacity, authorizes $3 billion for research and development, loan guarantees for innovative and low-emission generation, and standby insurance for companies that encounter regulatory delays and unanticipated setbacks for new technologies. Demand for electric power is expected to increase by 30 percent by 2030. Nuclear power provides a clean air alternative to fill part of

Table 1. U.S. Electric Power Generation
(Source: Energy Information Administration, in billion kilowatt-hours per day)

	2005	**2006**	**2007**	**2008**	**2009**
Coal	5.458	5.397	5.485	5.484	5.517
Natural Gas	1.872	2.012	2.227	2.232	2.307
Other Gases	0.011	0.011	0.011	0.011	0.01
Petroleum	0.32	0.164	0.168	0.152	0.158
Nuclear	2.142	2.157	2.21	2.196	2.205
Pumped Storage Hydroelectric	-0.018	-0.018	-0.02	-0.018	-0.016
Other Fuels	0.019	0.02	0.019	0.019	0.019
Renewables:					
Conventional Hydroelectric	0.732	0.784	0.672	0.692	0.707
Geothermal	0.04	0.04	0.041	0.038	0.037
Solar	0.002	0.001	0.002	0.002	0.002
Wind	0.049	0.073	0.088	0.121	0.144
Wood and Wood Waste	0.029	0.028	0.029	0.028	0.028
Other Renewables	0.036	0.038	0.04	0.042	0.044
Total Electric Power	**10.691**	**10.707**	**10.972**	**10.997**	**11.162**

the need; it is a safe method of generating power and the plants have operated at near 90 percent capacity since 2000. Nuclear-powered submarines and ships had traveled 136 million miles with over 250 reactors in service, and recorded 5,800 naval reactor-years of safe operation as of 2007; there have been no accidents or radioactive releases to date. These data should instill confidence in nuclear systems. An October 2007 national survey indicates that 69 percent of the public favors nuclear power production.

Radiation

Everyone is exposed to small amounts of radiation all the time – from cosmic radiation, rocks, soil, and air. In addition there are a number of medical procedures that entail radiation exposure such as x-rays, radiotherapy, and positron emission tomography (PET) and laboratory and field equipment for example, nuclear density meters for soil and x-ray fluorescence (XRF) analyzers. Acceptable doses for workers and the general public have now been established. A dose is the amount of medically significant radiation a person receives. There has been over 40 years of experience in applying international radiation safety regulations at uranium mines, and there are no ill effects for the miners that have been working in such mines. The International Commission for Radiological Protection (ICRP) has established recommended standards of protection for both members of the population and for workers. ICRP recommends that the additional dose above natural background and excluding medical exposure should be limited to one millisievert (1 mSv) (100 millirem) for the public and 20 mSv (2 rem) per year averaged over 5 years for radiation workers. These workers are closely monitored and wear dosimeters which are checked on a regular basis.

Mining

Modern mining companies adhere to these standards. The safety record of the uranium mining industry has been good. Radiation dose records compiled by a number of mining companies that are under the scrutiny of regulatory agencies have shown that employees of those firms are not exposed to radiation doses above the limits. In fact, the maximum dose is about half of the 20 mSv (2rem) per year and the average is about one-tenth of that. In many locations around the world the level of natural radiation is two or three times the limit.

Major mining companies have an effective and intense program of education and training for their workers. Dust in the mine, which is the main source of radiation, is controlled to minimize inhalation by a good, reliable forced-ventilation system. Strict hygiene standards are maintained for workers handling uranium oxide concentrate. (Ingested material is toxic and affects the kidneys, but is gradually discharged through the urine). Respiratory protection is mandatory in areas where the monitored air indicates that it is required.

Specifically in relation to mining uranium in Arizona, in the Arizona Strip and other areas surrounding the Grand Canyon the amount of waste rock that is generated is small because of the high grade of the ore. The waste can, therefore, be covered, so that it is not blown around by wind. In addition, the mine life for each breccia pipe is relatively short and the waste rock, and even construction concrete, can be placed back in the mine opening. The ore will be trucked out of the area, and the disturbed land reclaimed. There are examples of previously mined areas where the land has been restored so that it is not possible to distinguish it from the native landscape. Relatively small amounts of water will be used, and will be recycled. Wells will draw water from an aquifer, which is nearly 1,000 feet below the mines, so there is no possibility of the water flooding the mines. Thus there will be no long-term impact on the general area. Even during operation, the size of each mine is small, the footprint being 10 to 15 acres.

It is evident that reservations to uranium mining based on techniques used 60 years ago are exaggerated. There was little knowledge of how radiation from uranium affected humans at that time. Thus not only were the mining companies involved not cognizant of what precautions should have been taken, but so were the communities in which these operations were being conducted, and the regulatory bodies that governed these operations. Smoking was a widespread habit, even though it is extremely hazardous to uranium miners. And the practice of mining uranium ore during off-hours, without supervision or protection to make some extra money, was not uncommon. Now there is a plethora of regulations that are in place, and the mining companies are painfully aware of legacy problems.

Arizona Sets Records!

The value of Arizona's copper production set a new high of **$5.5 billion** and pushed the total value of mineral production to **$7.58 billion!** This is also a record.

Arizona Mineral Production

Commodity	2007 Value[3]
Clay (bentonite)	$1,730,000
Copper	5,540,000,000
Gemstones	1,580,000
Sand & gravel	597,000,000
Stone, crushed	116,000,000
Other[1]	1,120,000,000
Coal[2]	200,000,000
Total	**$7,580,000,000**

1) Includes cement, clay, lime, gypsum, gold, molybdenum, perlite, pumice, silver, salt, dimension stone, and zeolites.
2) Arizona Department of Mines and Mineral Resources estimated value for coal.
3) Unpublished U.S. Geological Survey (USGS) data, subject to change; data rounded and may not add to totals shown, final 2007 data will be published in the Arizona Chapter of the USGS Mineral Yearbook, Area Reports: Domestic 2007, volume II.

View of three of seven panels in the new Copper Gallery.

Museum News

by Dr. Jan C. Rasmussen, Curator

Plans for the Arizona Mining and Mineral Museum

Beautiful minerals and useful products - they all come from a mine. The Arizona Mining and Mineral Museum presents the educational message that the beautiful minerals and gemstones we enjoy and the products we use in our daily lives come from mines. This follows the Arizona Revised Statutes requirement that the Department of Mines and Mineral Resources promote the development of mineral resources in Arizona by technical and educational processes, including public seminars, conferences, and mineral displays. The state requires that the department maintain "a mineral museum as the state's depository for collecting, cataloging and displaying mineral specimens of various ores, gemstones, lapidary material, and other valuable mineral specimens."

Most of the components of a good museum are already present. The minerals, rocks, fossils, meteorites, gemstones, and lapidary items are well cataloged. There are interesting outside historic mining exhibits to draw the public's attention. There is ample space to display the mineral specimens and mining exhibits. And, more than 24,000 school children and 20,000 adults visit the museum each year. So, what are the plans that will enable the museum to become even better?

Mineral Gallery

The mineral gallery will continue to display beautiful minerals, although the cases will be rearranged to create distinct areas of interest. Arizona minerals will be displayed together in one portion of the mineral gallery by location or type of mineral deposit. Lapidary and gemstones will be displayed near the lapidary shop. Another area will emphasize themes (such as systematic mineralogy by the Dana system, colors, turquoise, quartz, calcite, crystal systems, periodic table, and others). Exhibits will satisfy Arizona curriculum requirements for science education by posing a question that can be answered by observing the minerals in the case. The uses of minerals in our daily lives will have special areas in the mineral gallery and second floor.

Current educational research as well as observations of children in the museum indicate that interactive exhibits are the most appealing to both children and adults. Simple educational exhibits are planned for a "Touch and Try" type of exhibit, such as mineral identification properties (streak, hardness, cleavage, magnetite in black sand, heavy versus light, and others.) An interactive rock identification exhibit will allow children to touch a probe to a button next to a rock and connect it with another button next to the names of the rocks.

Copper Gallery

Beautiful specimens from Arizona's porphyry copper mines are on display in the Copper Gallery in the new cases funded by the Phelps Dodge Foundation, along with explanatory panels depicting scenes from those mines. Interactive touch screen stations will be installed to explain the copper mining processes. The Copper Gallery contains a depiction of historic underground mining, but needs a good three-dimensional model of an open pit copper mine. A three-dimensional video presentation of minerals and copper mining processes may be installed via a GeoWall, which requires two projectors, a screen, and 3-D glasses for the viewers. Three-dimensional power point presentations of minerals, plate tectonics, and geological processes are commercially available. In the future, a three-dimensional movie of the processes of mining may be prepared.

Geologic history can be portrayed with fossils, rocks, meteorites, mountain building and volcanism, and Arizona ore deposits displayed at the appropriate age in the geologic timeline. Exhibits on mining for sand and gravel, gypsum, dimension stone, gemstones, limestone, salt, gypsum, and gold are also planned.

Other Exhibits

Another activity in the planning stage is the Great Globe project. A 400-foot diameter, three-dimensional representation of the Earth will be built by children around the world. The Museum may become the first printer site for 4th and 5th grade children to print three-dimensional, 4-inch on a side, triangular tiles of their corner of the world. Each child who participates will research the contents (ground surface color, people, animals, plants, and buildings on the first day of summer) of a triangle that represents 4.7 miles on each side, at a scale of 1:100,000. At this scale, the 3-D model of Arizona will be approximately 20 feet tall by 16 feet wide and will be displayed at the Museum. Publicly available topographic data from NASA and technical support will be supplied to the children by the Great Globe project. The children will come to our museum to print their 3-D tiles made of gypsum. The final globe is proposed to be constructed in several years at a site in south central Arizona.

Scale models or dioramas allow a large, complex series of processes to be viewed as an interrelated system. A "Mine-to-You," HO gauge (scale 1:87), moving model train diorama is planned to depict the various modern mining processes that copper ore undergoes to become copper wire. The processes of modern copper sulfide mining will be shown from mining copper sulfide ore through milling, concentrating, smelting, refining, and manufacturing. The copper leaching process from mining copper oxide ore through milling, leaching, solvent extraction, electrowinning, and manufacturing copper rod will also be shown. Above each of the buildings (Crusher, Concentrator, Smelter, Leach Pad, Solvent-Extraction/ Electrowinning Plant, Refinery, and Rod Mill) will be a video screen with a short video showing what happens inside the building or area. This "Mine-to-You" diorama is expected to be a three- to five-year project.

There will also be a life-size portion of a house to emphasize the uses of minerals in a house. The life-size portion of a kitchen will show the mineral components that make up a stove, refrigerator, microwave, wallboard, flooring, wiring, plumbing, and other items. The outside portion of the house will show the mineral components of aluminum siding, bricks, cement blocks, roof tiles, shingles, electric panel, gutters, and other items.

Your Support Is Needed

These improvements can occur with your help as volunteers and donors. Please help make the Arizona Mining and Mineral Museum a better place by donating your time and money to support the museum. As a state government agency, direct donations to the museum are tax deductible. Some 501(c)(3) organizations associated with the museum have also been very helpful in this respect.

The Arizona Mining and Mineral Museum fills the unique niche of educating people about the aesthetic and practical value of minerals and mines. With your help, the museum will be inspirational, educational, fun, and ever changing.

National Research Council Reports Released

Two members of the Department of Mines and Mineral Resources' team served on the National Council of the National Academies committees last year. The reports of these studies were published in March 2008.

Dr. Madan M. Singh, Director of the Department, served on the Committee of Assessing the Need for a National Defense Stockpile. The released report is entitled *Managing Materials for a Twenty-first Century Military*.

Dr. Mary M. Poulton, member of the Board of Governors of the Department and Head of the Department of Mining and Geological Engineering at the University of Arizona, served on the Committee on Critical Mineral Impacts on the U.S. Economy. The committee's report is entitled *Minerals, Critical Minerals, and the U.S. Economy*.

Both comprehensive reports are available online from the National Academies Press.

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